Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

ASTRONOMICAL COLLISIONS.

THE universe of space is, in one sense, full and crowded. Everywhere our telescopes find stars; and for every one we see there are probably hundreds, and even thousands, too faint or small or far away to reach our senses. And of this countless host of worlds not one is at rest, but all are rushing through space, free and unbridled, with velocities far exceeding anything in the range of our terrestrial experience. Our swiftest cannon-shot takes more than three seconds to go a mile, but the stars and planets seldom move slower than five miles a second, and some of them go two hundred. The veriest snail among them would overhaul a rifle-ball in the same sort of way that the rifle-ball would overtake a receding freight train. Is there not, then, danger of collisions? Have such collisions ever occurred; and, if so, with what consequences?

Now, in the first place, it is only in a sense, and rather a Pickwickian one, that space can be called crowded. True, stars are to be seen in every direction; but this is because our vision reaches so unimaginably far. If we restrict our consideration to bodies of respectable magnitude,—a hundred miles in diameter, for instance,—we ought rather to say that space, instead of being crowded, is almost inconceivably empty. Between any star or planet and its nearest neighbor, lie usually desolate distances of millions, or even millions of millions, of miles. If we assume, what is probably an under-estimate, that the region commanded by our telescopes is so vast that light takes a thousand years in coming to us from its outer confines, and, further, that the number of its stars is a thousand millions (the number visible with our largest telescopes is usually estimated at about sixty millions), then we find that the average distance from star to star must be about nine millions of millions of miles. This is not quite half the actual distance from the sun to our nearest stellar neighbor (α Centauri), according to the received value of its parallax; but it is a distance which quite defies the power of human comprehension. If two stars at such a distance were rushing straight toward each other with a speed of ten miles a second, it would require nearly thirty thousand years to bring them together. Represent the sun, as in Sir John Herschel's familiar illustration, by a globe two feet in diameter, so that oranges, cherries, peas, and pins'-heads would stand for the different planets at distances ranging from eighty feet to two miles, then, on that scale, α Centauri would be eight thousand miles away. Obviously, there is plenty of elbow room in the universe, and the chance of two stars accidentally jostling each other is far less than that of the collision of two bullets in mid-air over a battle-field. Still the possibility remains.

There is a prevalent impression that the immunity from collision between the heavenly bodies depends mainly on their being held in orderly orbits by central attraction; and it is true that their orbital constraints make it quite impossible for the *planets* to collide with each other, or even to approach each other very closely. But a very impressive picture is sometimes drawn of what would happen if the earth, for instance, should some time free herself from the bonds of gravitation— how she would fly off into space (which is true, of course), and soon dash herself to pieces against some other wandering world (which is not true at all, or at least not probable). Most likely, if gravitation were suddenly to cease, the earth would travel for millions, not of years, but of ages, without ever encountering anything more important than meteors, such as are now continually falling upon her surface. And these meteoric encounters, even, would probably be far less frequent than at present, since there is reason to suppose that such bodies are much more numerous in the neighborhood of the sun, and of other great stars, than in the rest of space.

Evidently, however, the attractions between a wandering star and others lying near its path must considerably increase the chances of collision, though not to so great an extent as perhaps might be supposed. A body entering our system at a distance from the sun one hundred times as great as the radius of the earth's orbit, and moving with no more than the velocity natural to a comet at that distance (about $2\frac{2}{3}$ miles per second), would not strike the sun unless its path were directed within less than half a degree (23.′4) of the sun's center; and if its velocity were greater, the aim would have to be still more accurate to score a hit. If bodies were shot into space at random from the position and with the velocity indicated, only about one in eighty-six thousand would hit the sun. Were it not for the sun's attraction, however, the proportion would be twenty thousand times smaller still—only one in seventeen hundred millions.

It is obvious, therefore, that encounters between heavenly bodies of considerable magnitude must be extremely rare. There is not in all the astronomical record a single certain instance of such an occurrence. And yet it may confidently be asserted that some time or other in the past such events must have happened, and some time in the future will happen again; simply for the reason that, in a sufficient length of time, the most improbable things, if only not impossible, are sure to come to pass. Now, it is almost certain that the stellar motions are not such as to render collisions impossible: the planets, it is true, as has been said before, can never run into each other, because of the size and nature of their orbits, but, so far as can now be ascertained, nothing of the sort holds good for the motions of the stars. We already know enough about some of their so-called "proper motions" to be quite sure that, as a fact, they are not traveling in any simple curves around any common center, and also that some stars are flying through space with such velocities that no attraction, such as can reasonably be supposed to act in the premises, can control them. Nor does theory, any more than observation, indicate a structure of the stellar universe at all analogous to that of the planetary system. Among the stars there is no central dominance and no imperial power, but we have to do with a republic of comparatively free and independent members.

Sir William Thomson is therefore fully justified in writing: "It is as sure that collisions must occur between great masses moving through space as it is that ships, steered without intelligence to prevent collision, could not cross and recross the Atlantic for thousands of years with immunity from collision." Undoubtedly, the chance of an encounter between a pair of heavenly bodies, selected at random, is trifling, almost beyond the power of computation, and the intervals of time between such catastrophes, in that part of the heavens subject to human observation, must be, on the average, enormous; but yet, in infinite time and unbounded space—somewhere or other now, sometime or other here—such things are happening, or will come to pass.

If ever two great worlds do really meet in this way, it is possible to predict some of the consequences. To use the technical language of science, "their energy of molar motion will be converted into various forms of molecular and potential energy"; which, translated into the vernacular, means that there will be evolution of heat and light, while at the same time the solids present will be wholly or in part liquefied, the liquids vaporized, and the vapors and gases rarefied and expanded. The intensity of the action will depend, of course, mainly upon the mass and swiftness of the colliding bodies; but an easy calculation shows that if our earth were ever to meet another globe like herself, and moving with the same velocity, heat enough would be generated by the shock to transform them both into a huge ball of vapor; unless, indeed, the central core of the earth is much colder and more refractory than usually supposed. At any rate, the quantity of heat developed would be sufficient to melt, boil, and completely vaporize a mass of ice fully seven hundred times that of both the colliding worlds—an ice planet 150,000 miles in diameter.

If, however, the impinging masses were, to begin with, mainly gaseous (as the sun seems to be), the effect might be curiously different. Heat would, of course, be generated, just as in the case of solid bodies; but, as a consequence, apparently most paradoxical, the resulting nebula might actually be cooler than either of the bodies before the encounter; of course, it would be immensely expanded in volume. Just as a gaseous mass, contracting under its own gravity from loss of heat by radiation at its surface, continually rises in temperature, so a similar mass, expanding against its own gravity from accession of heat within, may fall in temperature,—nay, must fall, if the body is composed of "perfect" gas. Of course, immediately after the collision, and before the ultimate expansion of bulk was attained, the temperature and brilliance of the mass would be for a time vastly increased, but the final result would be as stated.

In a preceding paragraph it was said that we have not on the astronomical records a single certain instance of any collision between bodies of considerable size. But there have been several cases of a most remarkable phenomenon, which perhaps may owe its explanation to such encounters. Stars, never before visible, or else known only as faint and minute, have suddenly blazed out, shining sometimes with the brilliance of Sirius, or even Venus, and afterward faded away to their original insignificance. Such was the famous star of 1572, so carefully observed by Tycho Brahe. As recently as 1866, and again in 1876, similar things have happened, though these later stars were less conspicuous. The star of 1876 (in the constellation of Cygnus) had long been known and catalogued as a telescopic star of the ninth magnitude, with nothing to distinguish it from any of the common herd. On November 24th it suddenly shone out as bright as the pole-star. Schmidt, of Athens, who discovered it, had been observing that very region of the sky only four days before, and no such object was then visible. The intervening days were cloudy, so that we cannot tell precisely the hour when it first blazed up, but evidently its increase of brightness must have been extremely rapid. Immediately after Schmidt's observation it began to fade, but it was two weeks before it fell below the sixth magnitude and became invisible to the naked eye, and it was more than a year before it resumed its original faintness. Its whole course was carefully watched with the spectroscope. At first, and for some months, like the star of 1866, it showed conspicuous in its spectrum the lines of hydrogen, together with other lines of uncertain origin. As its brightness decreased the hydrogen lines faded still more rapidly, leaving other lines more prominent, until, at last, the spectrum, instead of becoming that of an ordinary star, came to consist simply of three bright lines, the spectrum of a nebula, and it continues such to this day. Whether this is, or is not, the same spectrum it had before the outburst no one can say, as it had never been observed with the spectroscope before.

Now, I am very far from asserting that this was a case of collision; and yet it is clear enough that the whole course of phenomena was very much what might have been expected if it were. At any rate, the collision hypothesis is held and defended by several astronomers of authority, and the principal reason for preferring a different possible explanation lies in the fact that these "temporary stars," as they are called, are far too common to be probably due to stellar encounters. We have on record eight since the Christian era, and no less than three of them since 1840.

It is hardly necessary to say, that if any retinue of planets attends such a star, its sudden blaze cannot fail to carry disaster and destruction to all life upon them. We can conceive that forms of life may be possible under almost any imaginable physical conditions, provided only the course of events by which they have been reached has been gradual enough to allow the necessary adaptations. One would not dare to deny the possibility of life of some kind on the airless moon, or even on the sun itself. But all we know makes it certain that no planetary life could survive the tremendous and catastrophic change of conditions involved in a sudden thousand-fold increase of the solar radiation.

Thus far we have been considering only collisions of stellar masses. But space is filled also with minor particles, separated from each other only by intervals of a few hundred miles; and these, in the form of meteors and shooting-stars, are rushing through space, dropping continually upon the larger worlds, increasing their size, and adding to their stores of heat and energy. Every year the earth encounters nearly three thousand millions of them, according to the estimate of Professor Newton, ranging from the merest particles to masses of several hundredweight. Very probably, also, the comets belong to the same category, being really nothing but larger meteors, or flocks of small meteors, or perhaps even only puffs of meteoric dust. Nearly all the meteors which strike the earth are very minute. Perhaps a hundred or so reach the ground each year as recognizable masses of stone or iron, weighing from an ounce or two to some hundreds of pounds, but all the rest are dissipated in the upper air, and never come down unless as impalpable dust, not to be certainly identified. The whole amount of matter falling daily upon the earth from outer space is probably about one hundred tons on the average (it is variously estimated from twenty-five to five hundred). A hundred tons is in itself a very considerable quantity, but utterly insignificant as compared with the mass of the earth, and entirely incapable of appreciable effect upon our temperature. Assuming even the largest estimate (five hundred tons a day), and also that the average velocity with which meteors enter our atmosphere is fifteen miles a second (probably considerably too large), we find that the heat annually received from them by the earth is only about fifty-three calories for each square meter of her surface,—less than would be imparted by two minutes' perpendicular sunshine, and only about $\frac{1}{60,000}$ of the heat actually received from the sun in a year. Retaining the same extravagant estimate of five hundred tons a day, it appears that the earth's diameter would grow an inch in about one hundred millions of years, and that her distance from the sun would be reduced about eighty-three feet in a million years, in consequence of the resistance experienced in moving through the meteoric swarms.

It would not, however, be just to the general reader to dismiss the subject without fair notice that some most eminent astronomers hold views at variance with those above expressed. The late Professor Peirce maintained to the end that the heat of the sun is chiefly due to the impact of meteors, and also that the earth itself receives as much heat from meteors as from the sun, a necessary result if the solar heat is really so produced. Of course, we have no space to discuss the matter here, and must be content with merely saying that the quantity of matter which falls upon the earth, if his idea is correct, ought to be easily noticeable, amounting to about fifty tons a day on each square mile. It involves also serious difficulties in the planetary theory.

So far as human beings are concerned, the most important question connected with our subject is whether anything is to be feared from comets, as a consequence either of collisions with the earth or of their fall into the sun. It may be said, just as of the stars before, first, that cometary collisions, either with sun or earth, must be very rare occurrences; and, secondly, that they are practically certain to happen sometime or other. Babinet computed, on the one hand, that a comet would strike the earth on the average about once in fifteen million years; on the other, we know at least three comets whose orbits cut the earth's path so closely that, if they should ever reach the crossing at the same time as the earth, a collision must occur. These comets are known as Biela's, Tempel's, followed by the Leonid meteors in its train, and the comet of 1862, which precedes the Perseids. One of the three, however (Biela's), has probably ceased to exist as a comet, and it is quite possible that the other two may vanish in the same way before we meet them.

As to cometary encounters with the sun, no comet has yet been known actually to strike the sun, but several have grazed very near it. The great comet of last year brushed through the corona, and came within three hundred thousand miles of the photosphere, and there is no assignable reason why some other comet should not actually pierce it.

As to the consequences of a comet's collision with the earth, it is impossible to predict them with scientific certainty; probably, however, they would be insignificant. We know absolutely that the whole quantity of matter in a comet (technically, its "mass") is extremely small compared with that of the earth; but just how small no one can say. It is impossible to contradict authoritatively either the man who says he could carry a comet home in his pocket if properly packed, or one who asserts that a comet's nucleus is equivalent to an iron ball one hundred miles in diameter. An attempt has been made to get at the density of the central nucleus on the assumption that it holds to itself the enormous volume of the head and envelopes by its gravitational attraction, as if the surrounding nebulosity were an atmosphere in equilibrium around the nucleus; but the assumption is more than doubtful, and the derived conclusion, of course, is of little value. It seems, on the whole, more probable that a comet is throughout only a cloud of dust and vapor—a mere smoke-wreath—than that there is at the center any solid kernel of preponderant mass.

If a comet really has at the center any great mass of stone or iron, or even a close-packed swarm of aerolites weighing a ton or two apiece, collision with it would of course be a most serious matter, spreading devastation and conflagration possibly over half the globe at once; not amounting, probably, to anything like a destruction of the world, but far more disastrous than any earthquake or volcanic eruption. It is far more likely, however, that the encounter with a comet would be entirely harmless,—simply a most magnificent and brilliant shower of shooting-stars lasting for an hour or two,—a phenomenon which one might well desire to see.

As for the effect of a collision between a comet and the sun, in respect to which there has been much disquieting speculation of late, the probability is that we on the earth should never know it, unless we happened to be expressly watching the event. For a few minutes, just as the nucleus was piercing the photosphere, there might be some unusual flash of brilliance and a fine outburst of solar prominences, followed, perhaps, and very probably, by intense magnetic and auroral disturbances on the earth; but the main thermal transformation of the impinging energy would be effected far below the visible surface of the sun, and would result merely in a slight expansion of its bulk, far too slight to be detected by terrestrial astronomers.

C. A. YOUNG.